LONG TERM SUSTAINABILITY ON THE MOON

NASA LUNAR SCIENCE INSTITUTE CONFERENCE

JULY 22-24, 2008

Robert S. Wegeng

Pacific Northwest National Laboratory

Pacific Northwest
NATIONAL LABORATORY

Items from Yesterday

- We're *returning* to the Moon
- Beginning the next step in the *settlement* of the solar system
- Science, security & the economy
- Science – *of, on and from the Moon*
- International partnerships
- Bringing the Moon into Earth's economic sphere
- Infrastructure development
- Wealth creation
- Space resources

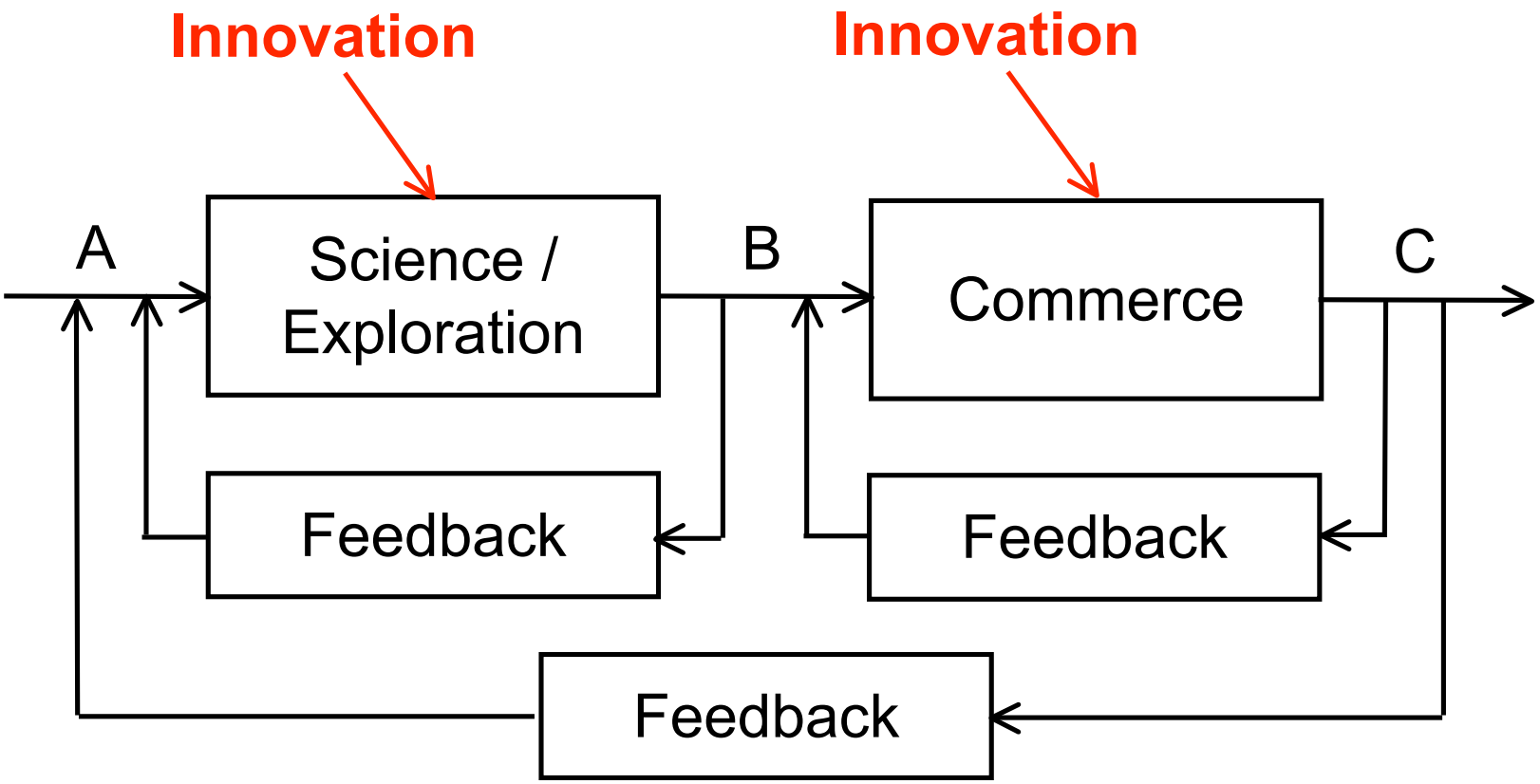
- "From the Earth to the Moon"

Sustainability

- One of many possible metrics:

$$Productivity = \frac{Value}{Cost}$$

Sustainability // Feedback Loops



Pacific Northwest
NATIONAL LABORATORY

Apollo Program

- Was the Apollo Program Sustainable?
- Sustainability isn't just about politics
  - *Value*
  - *Cost*
  - *Productivity*
  - *Energy & Resources*
- *Think like an* ***Economist***

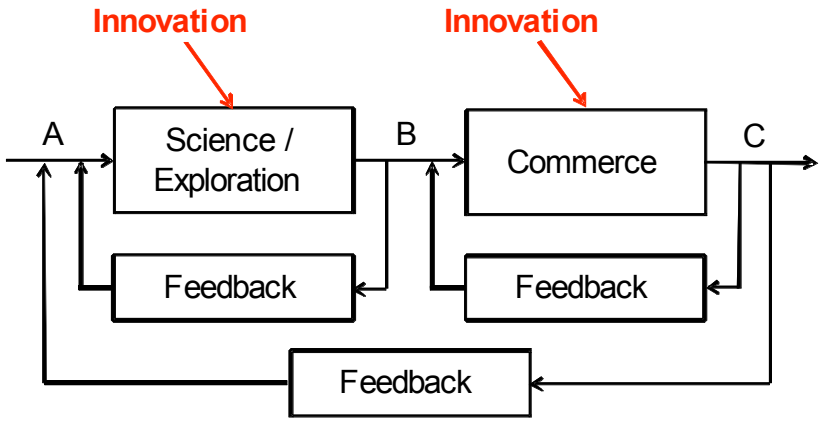
Pacific Northwest
NATIONAL LABORATORY

Historical Precedents

- **17th Century**
  - Jamestown
  - Other New World Colonies
- **18th Century**
  - United States of America
- **19th Century**
  - Erie Canal
  - Louisiana Purchase, Lewis and Clark
  - Transcontinental Railroads
- **20th Century**
  - Electricity
  - Automobiles and Air Travel
- **21st Century**
  - The Vision for Space Exploration
  - The Robotic International Lunar Network
  - Manned Outpost

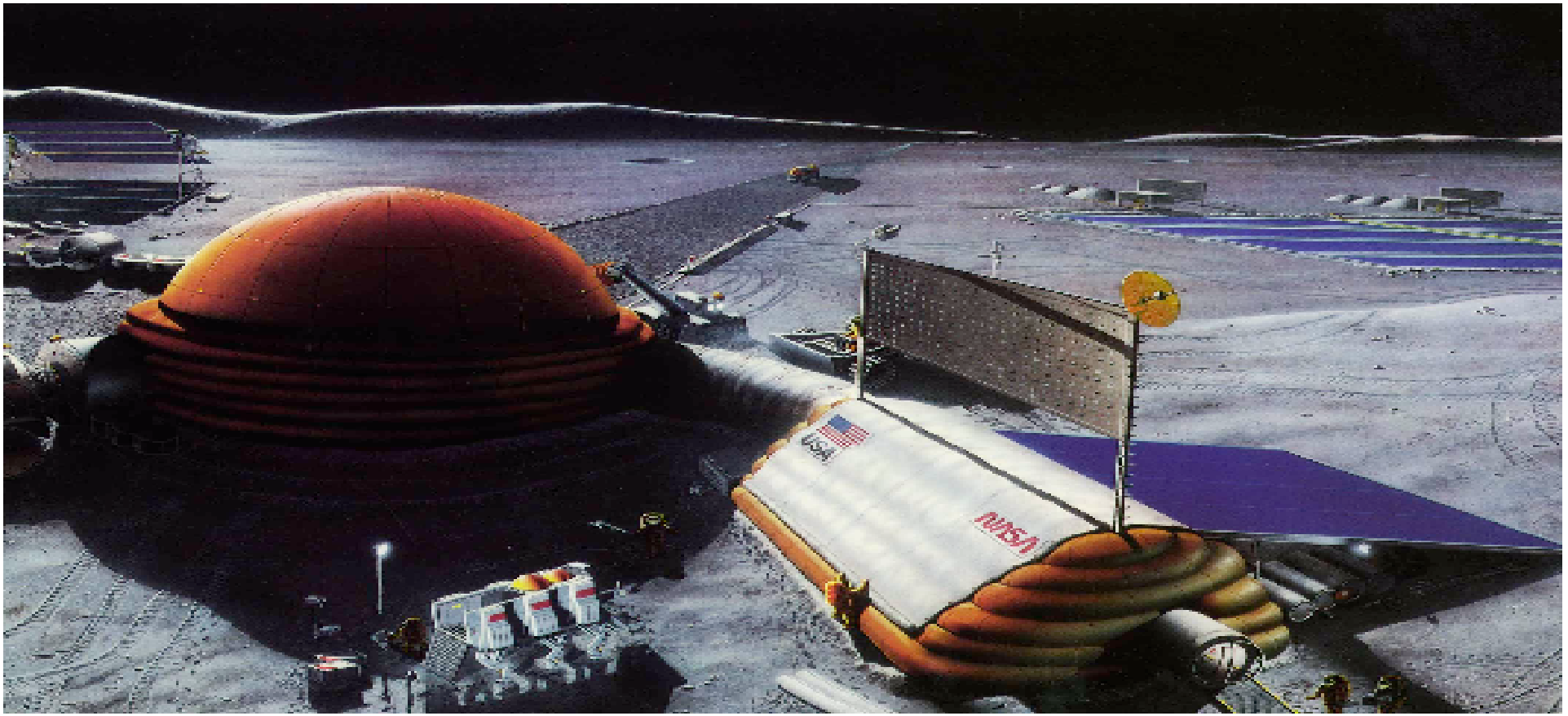
Historical Precedents

- The Louisiana Purchase
  - Purchased from France
  - President Jefferson commissioned Lewis and Clark on a journey of exploration to the Northwest
  - “The Northwest won’t be settled for 1,000 years” – Thomas Jefferson
- Steam Engines
  - Paddlewheel Steamboats
  - Railroads

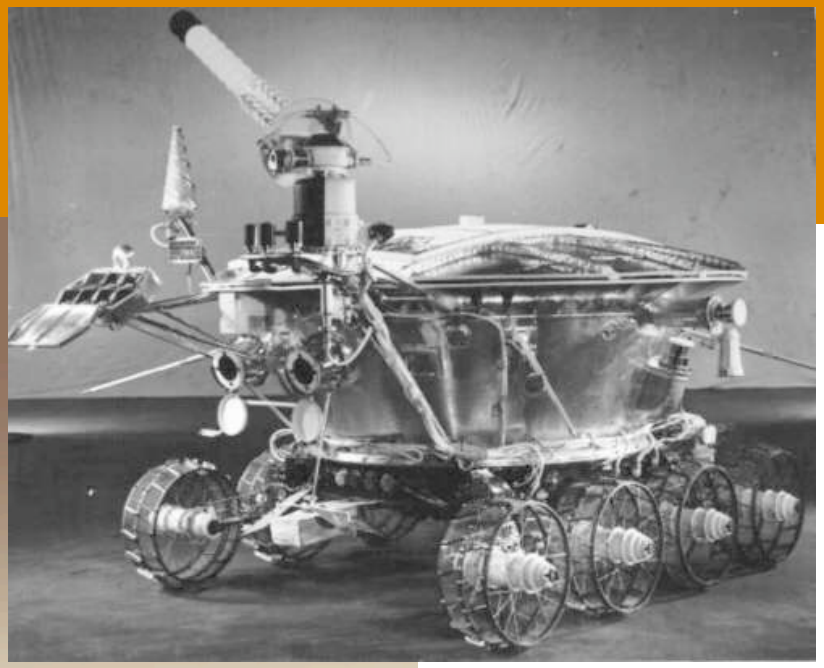


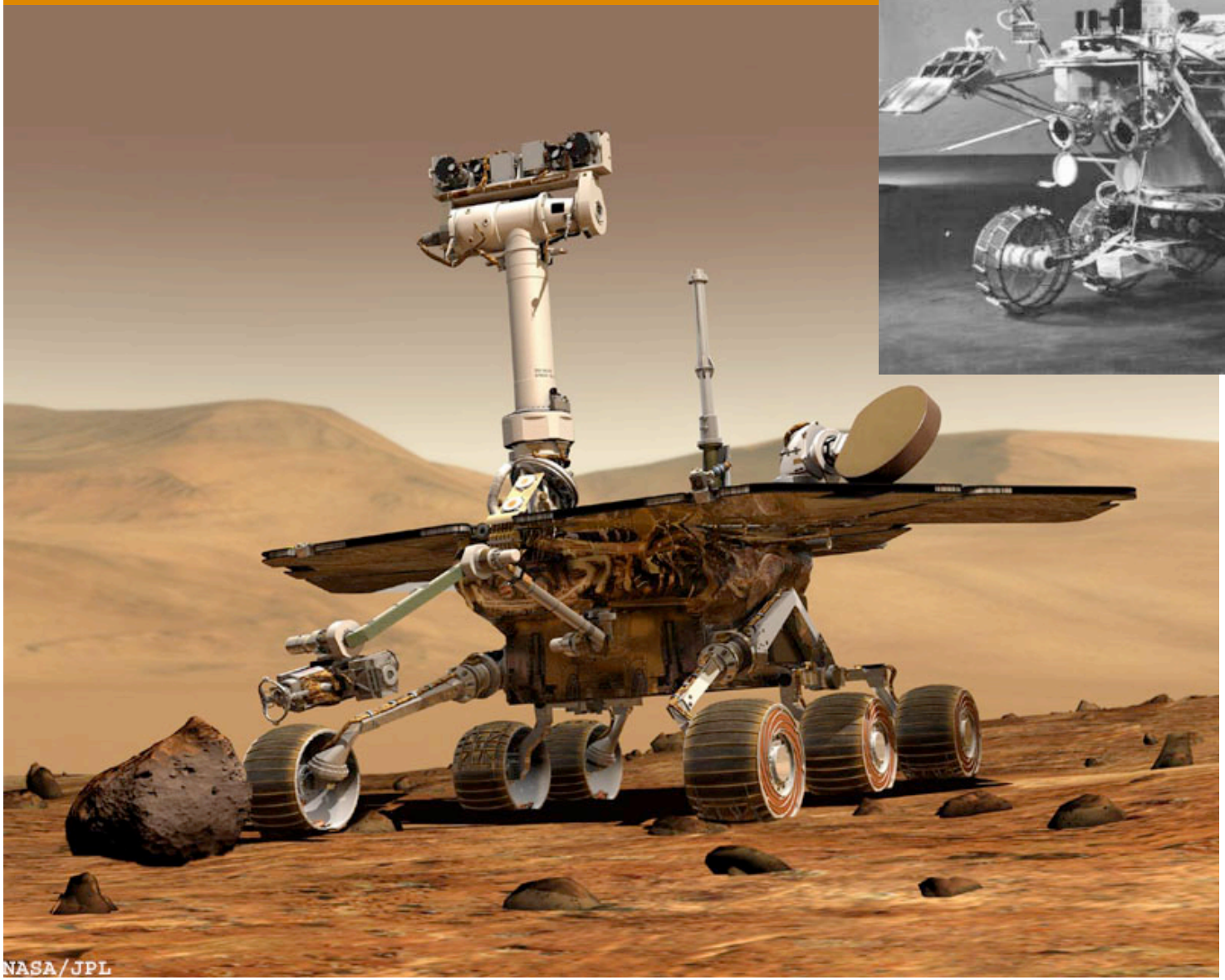
Lunar Resources

- Oxygen (for breathing, power generation, propulsion)
- Hydrogen and other fuels
- Structural materials (Al, Ti, Fe)
- Electronics materials (Si)



Rovers





Pacific Northwest
NATIONAL LABORATORY

Rover Productivity

- How do we improve the productivity of a rover system?

Perform Science & Exploration

Engage Multiple Institutions

Use Advanced Electronics

Enable Years of Operation

$$Productivity = \frac{Value}{Cost}$$

Minimize Mass

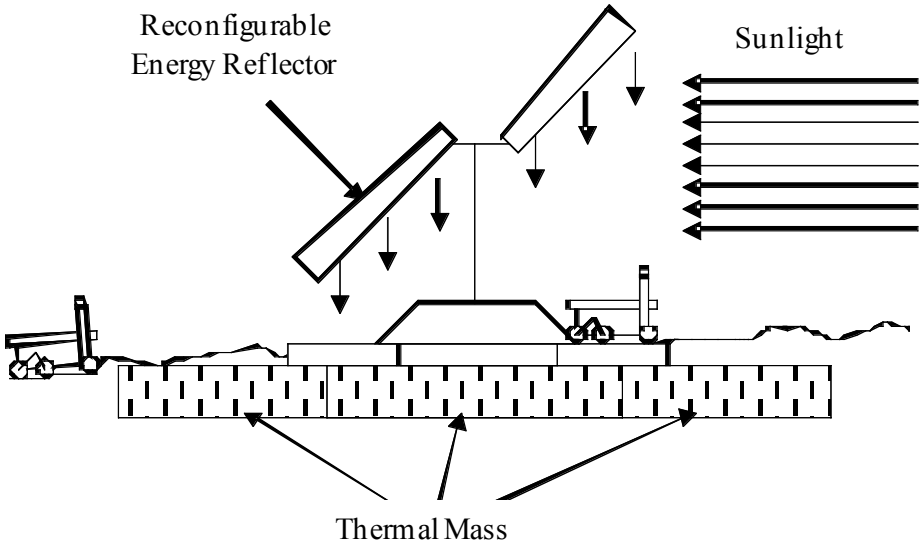
Deploy Multiple Units

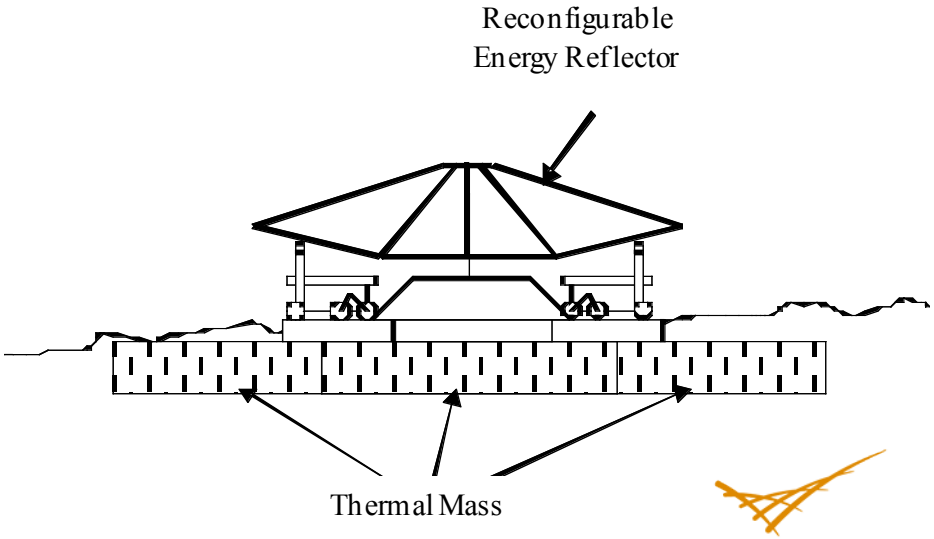
Standard Functions

Standard Interfaces

Thermal Wadi -- Concept

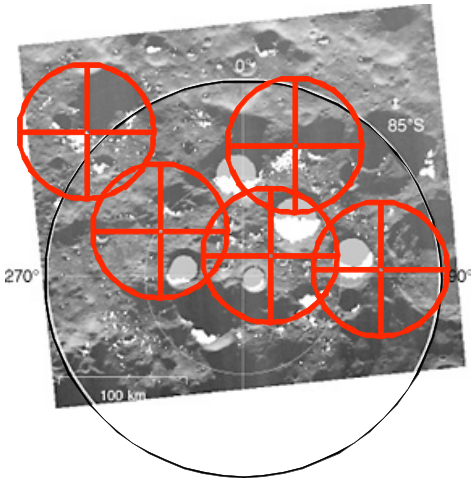
- Wa•di = An oasis
- Thermal Wadi = An oasis where the resource of value is thermal energy (heat)
- From a Thermal Wadi, a rover can explore a large exploration zone during the lunar day

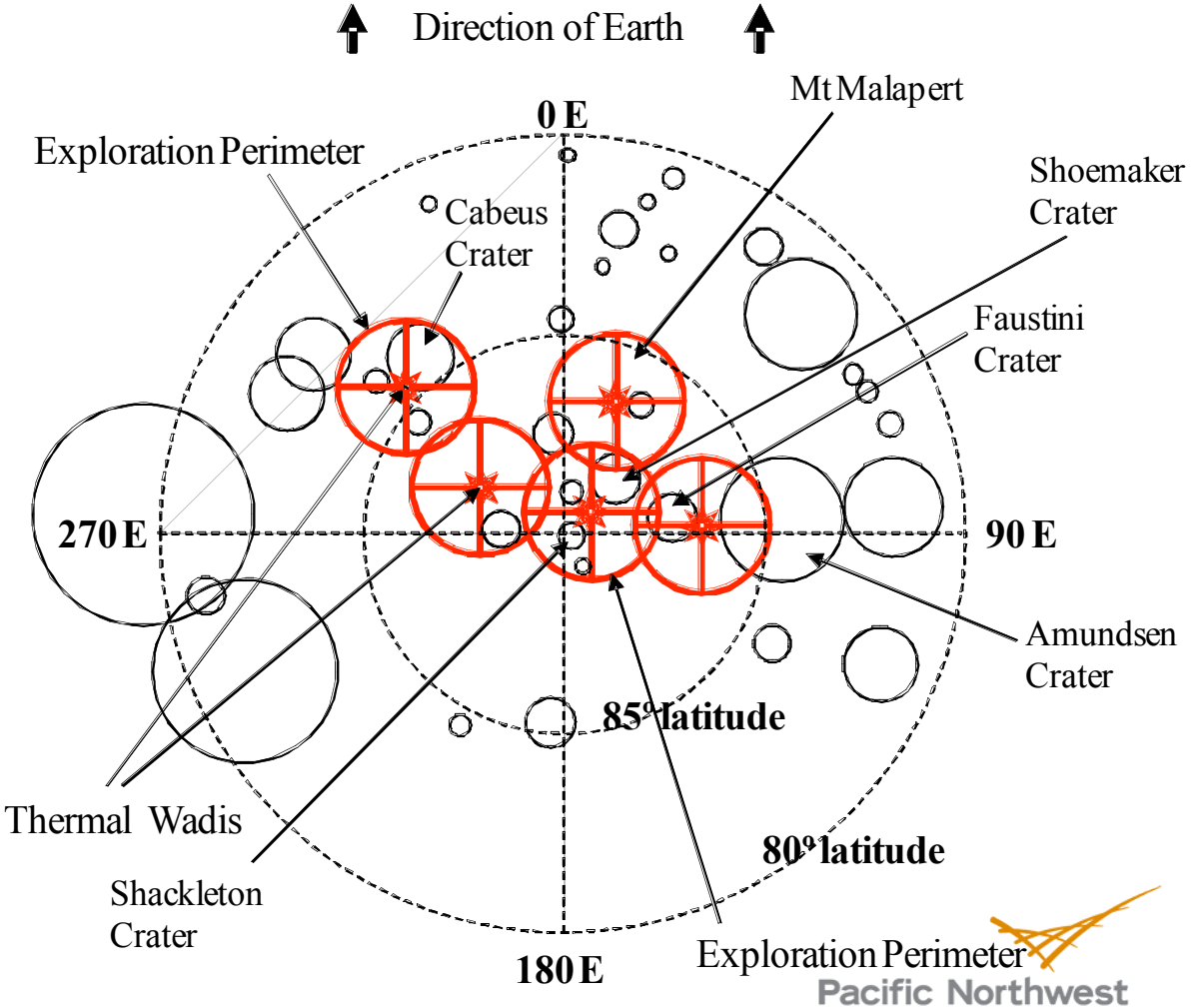




Pacific Northwest
NATIONAL LABORATORY

Thermal Wadi Networks





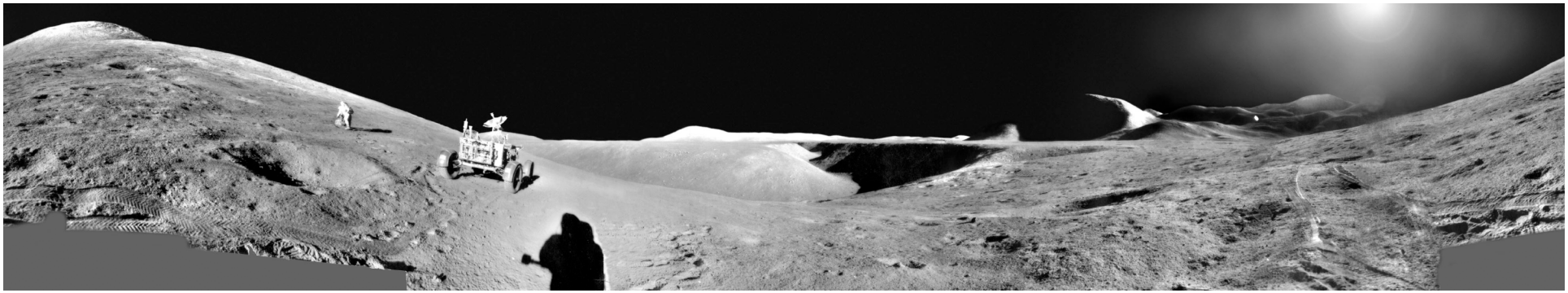
Pacific Northwest NATIONAL LABORATORY

Conclusions

- Sustainability
  - Productivity
  - Cost
  - Value
  - Resource Potential
  - Feedback Loops
- *Innovation rules!*
- Think like an *Economist*

The rules of *Orbital Mechanics* must be adhered to in order to get scientific instruments to the lunar surface.

The rules of *Economics* must also be adhered to in order to make the return to the Moon SUSTAINABLE.




“From the Moon to the Earth”

Thermal Wadi – Methods of Making…

- Use lunar regolith
- Use solar energy to transform the thermophysical properties of the regolith (e.g., melting)
- Alternately, use microwaves to sinter the regolith into solid units
- Alternately….

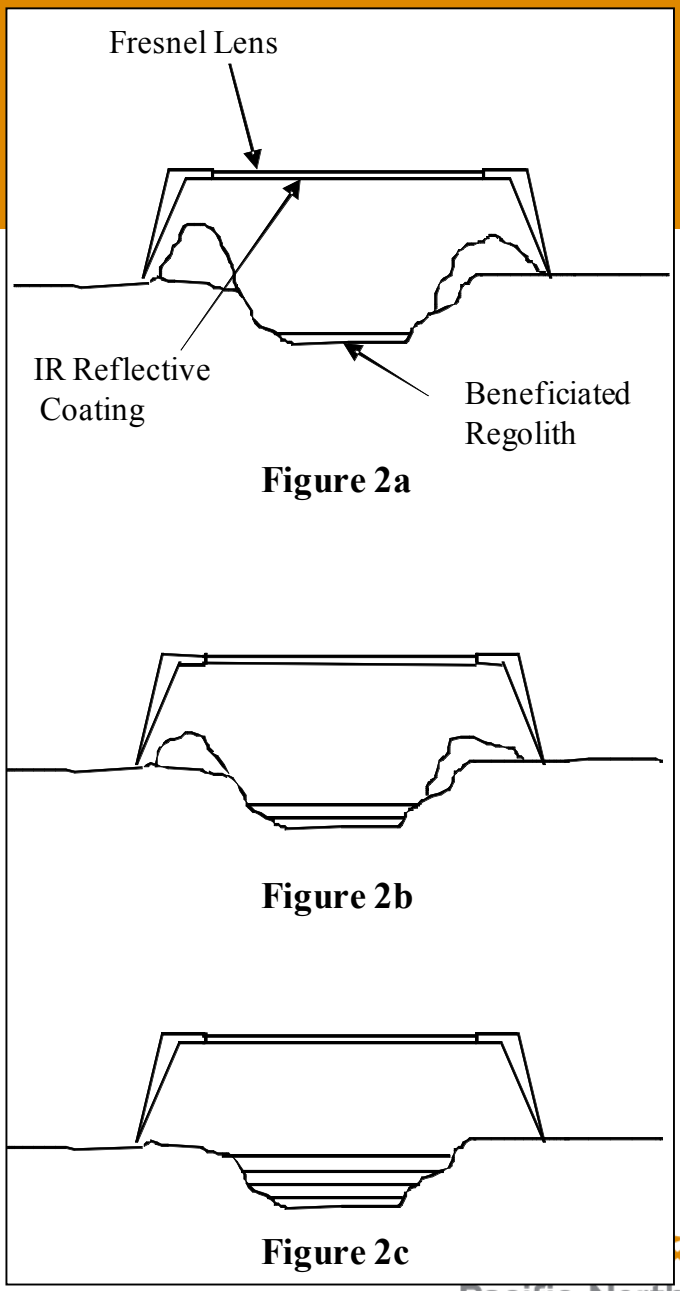


Figure 2a

Figure 2b

Figure 2c

Pacific Northwest NATIONAL LABORATORY

Thermal Wadi – Preliminary Thermal Analysis

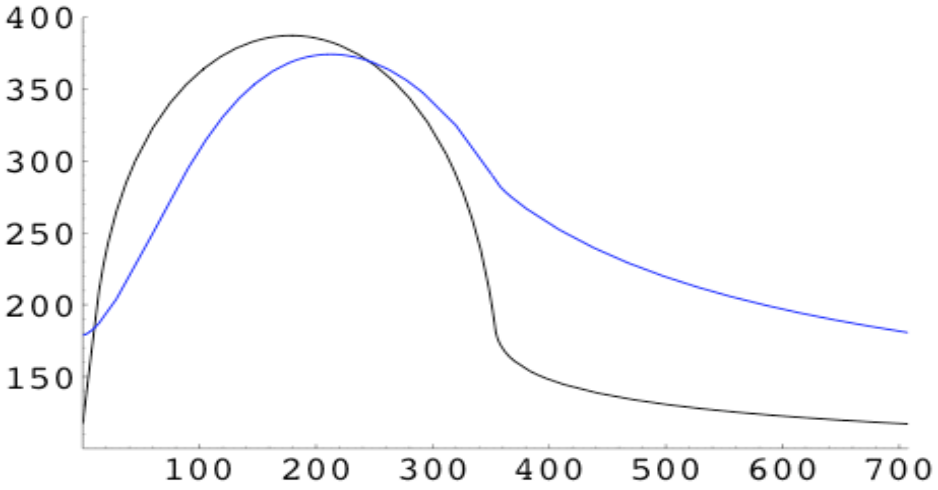


Figure 3a

Surface temperature at steady state in a 27-day diurnal cycle. Black curve – native regolith. Blue curve – 50 centimeter deep layer whose thermal properties are the same as basalt rock. Surface emissivity is assumed to be 0.90 for both cases.

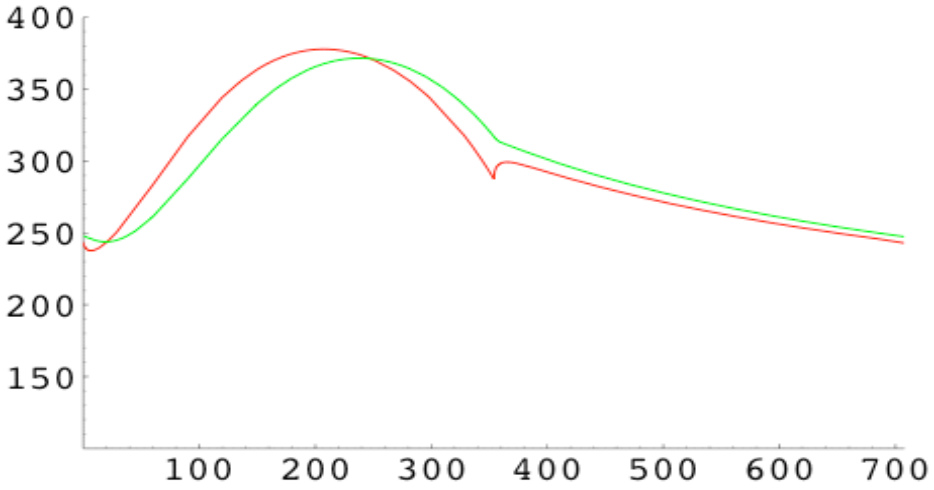


Figure 3b

Surface temperature (red curve) and temperature at mid-depth (green curve) at steady state in a 27-day diurnal cycle. The medium is a 50 centimeter deep thermal mass with the thermal properties of basalt rock. Surface emissivity is assumed to be 0.90 during the lunar day and is effectively reduced to 0.25 during the night through the use of an IR reflector.